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EXPERIMENTAL

Epidemiology of systematic reviews in imaging journals: evaluation of publication trends and sustainability?

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Abstract

Purpose To evaluate the epidemiology of systematic reviews (SRs) published in imaging journals.

Methods A MEDLINE search identified SRs published in imaging journals from 1 January 2000–31 December 2016. Articles retrieved were screened against inclusion criteria. Demographic and methodological characteristics were extracted from studies. Temporal trends were evaluated using linear regression and Pearson's correlation coefficients.

Results 921 SRs were included that reported on 27,435 primary studies, 85,276,484 patients and were cited 26,961 times. The SR publication rate increased 23-fold (r=0.92, p<0.001) while the proportion of SRs to non-SRs increased 13-fold (r = 0.94, p<0.001) from 2000 (0.10%) to 2016 (1.33%). Diagnostic test accuracy (DTA) SRs were most frequent (46.5%) followed by therapeutic SRs (16.6%). Most SRs did not report funding status (54.2%). The median author team size was five; this increased over time (r=0.20, p<0.001). Of the studies, 67.3% included an imaging specialist co-author; this decreased over time (r=-0.57, p=0.017). Most SRs included a meta-analysis (69.6%). Journal impact factor positively correlated with SR publication rates (r=0.54, p<0.001). Magnetic resonance imaging (MRI) and 'vascular and interventional radiology' were the most frequently studied imaging modality and subspecialty, respectively. The USA, UK, China, Netherlands and Canada were the top five publishing countries.

Conclusions The SR publication rate is increasing rapidly compared with the rate of growth of non-SRs; however, they still make up just over 1% of all studies. Authors, reviewers and editors should be aware of methodological and reporting standards specific to imaging systematic reviews including those for DTA and individual patient data.

Key Points

- *Systematic review publication rate has increased 23-fold from 2000–2016.*
- *The proportion of systematic reviews to non-systematic reviews has increased 13-fold.*
- *The USA, UK and China are the most frequent published countries; those from the USA and China are increasing the most rapidly.*

Keywords Meta-analysis · Epidemiology/methods and epidemiology/trends · Publications/trends · Research design/trends · Diagnostic imaging/trends

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Abbreviations

DTA	Diagnostic test accuracy
IPD	Individual participant data
IQR	Interquartile range
JIF	Journal impact factor
PRISMA	Preferred Reporting Items for Systematic reviews and Meta-Analyses
Q_1	First quartile (25th percentile)
Q_3	Third quartile (75th percentile)
SR	Systematic review

Introduction

Systematic reviews (SRs) and meta-analyses have become a staple in research; knowledge synthesis can have an important influence on clinical decision-making, guidelines and policy [1]. There has been a threefold increase in the publication of SRs over the last few decades; this increase has out-paced the overall growth of research [2, 3]. Between 1991 and 2014, MEDLINE indexing of all articles increased by 153%, while SR indexing increased by 2,728% [4]. Recognition of the value of a well-conducted SR and its strength relative to its single study components may be contributing to this disproportionately larger increase [2]. Not only can the pooling of multiple studies increase precision and narrow confidence intervals, SRs can allow for sufficient sample sizes for subgroup or regression analyses that would otherwise be difficult in individual studies [1, 5, 6]. However, other potential factors may be driving the increase in the number of published SRs. One driver may be financial incentives for publication. Some institutions offer incentives for publication irrespective of the quality of the publication or its impact [2, 7].

Given the increasing number of biomedical journals, SRs may also be more likely to be published even if the topic overlaps with a previously published SR [2], or if quality standards have not been met. Addressing potential quality and duplication issues in SRs should be a priority for imaging journals and researchers, as these practices contribute to wasted resources in research [8–10]. It is not clear whether the aforementioned publication trends hold true among imaging journals. For example, Tunis et al identified an improvement in the completeness of reporting and quality of SRs in radiology journals [11], while McGrath et al identified an increasing number of diagnostic accuracy systematic reviews published in imaging journals over the last decade [12]. However, the reporting characteristics, subsequent impact in literature, and publication rates of SRs in imaging journals have not been well studied. The purpose of this study is to evaluate the epidemiology and characteristics of SRs published in imaging journals including the number of SRs published per year and the annual proportion of SRs among all published studies, and evaluate for trends over time.

Methods

A protocol for this study was registered a priori on the Open Science Framework (see: https://osf.io/rnvrz/). Several analyses discussed below were added following the registration of the protocol.

Definitions

A SR is a type of scientific study that identifies all relevant studies on a specific topic based on a comprehensive search strategy, and summarises their findings provide a higher level of evidence than any of the individual included studies [13, 14]. A diagnostic test accuracy (DTA) SR specifically includes and summarises the evidence for DTA studies for a specific index test (e.g. MRI for detection of prostate cancer), or compares two different tests [15–19]. A meta-analysis is a statistical method that provides a single summary estimate (such as treatment effect, diagnostic accuracy, etc.) with greater statistical power by pooling results from the individual studies identified by a SR (when applicable) [13, 14, 20]. While a traditional meta-analysis involves combining aggregate study-level data, an individual participant data (IPD) meta-analysis involves pooling the raw individual patient level data for each study [21]. A network meta-analysis compares multiple interventions/treatments both directly (within studies) and indirectly (across multiple studies) based on a common comparator [22].

Search strategy and eligibility criteria

A search of MEDLINE was performed to identify SRs published from 1 January 2000 to 31 December 2016. The Montori method was used as a search strategy to identify SRs (search details are given in Supplementary Online Material, Appendix 1) [23]. The search was limited to the English language and to imaging-specific journals based on the 2015 Thomas Institute of Science Information list of imaging journals [24], corresponding to 72 journals (Supplementary Online Material, Appendix 2). As per the PRISMA [13] and Cochrane Collaboration [14] definitions of SRs, we included studies that identify, select, critically appraise, and analyse a group of studies to answer a clearly formulated question. Additional inclusion criteria were: published in English and in one of the listed imaging journals, and providing either a study flow diagram or specified searched databases.

Study selection

The initial search results were imported into a reference manager software (Reference Manager 11; Thomson Reuters, Toronto, ON, Canada) for level one screening. Level one screening involved independent title and abstract review, against the stated eligibility criteria, performed by two investigators (MA, radiology resident, and AA, staff radiologist). A pilot screening of the first 50 papers was conducted in duplicate to ensure high levels of agreement. A kappa value was calculated to determine inter-observer agreement for the pilot screening exercise. Discrepancies were resolved by consensus. The full-text articles were then retrieved for included SRs for level two screening (performed by MA, AA and TAM, a medical student). The full-text articles were then reviewed against eligibility criteria.

A broader MEDLINE search was performed to identify the total number of all types of publications in our predetermined list of radiology journals from 1 January 2000 to 31 December 2016. For search please see Supplementary Online Material, Appendix 3.

Data extraction

Retrieved full-text articles were uploaded onto a systematic review software program (DistillerSR; Evidence Partners, Ottawa, ON, Canada). Initially, the first five studies were all extracted by MA, AA, TAM, MDFM (a staff radiologist with expertise in DTA SRs) and KDC (a researcher in journalology) in order to pilot the data extraction form, and if necessary to make changes to this form. A further 25 studies were extracted in duplicate by all investigators, in order to improve familiarity and consistency for this phase. Discrepancies were resolved by consensus. Data extraction was performed independently on included studies by multiple investigators (MA, AA, TAM, MDFM, KDC and JPS, a Masters student in epidemiology, as well as by the following medical students: BB, RAF, FN and ADS).

The following data items were extracted using predefined forms created on DistillerSR: type of SR (DTA, therapeutic intervention or other); inclusion of meta-analysis and type (IPD meta-analysis, network meta-analysis or other); year of publication; country and continent of corresponding author; number of authors; journal of publication; number of included studies and/or patients in SR (if reported); number of times the study has been cited per year via the Thompson ISI database; funding status; imaging modality and subspecialty of interest [12]; and the presence of any imaging specialist co-author, including radiologists, nuclear medicine staff or other physicians with imaging fellowships in the author departmental affiliations [25].

Data analysis

We identified annual publication rates of SRs, as well as the annual proportion of SRs among all published studies in the included journals. In doing so, we looked at how the rates and proportions have changed since the year 2000. We stratified this data according to journal, country and continent of publication.

We evaluated the characteristics of SRs based on number of citations per year, including the country of publication, availability of funding, size of the author team and whether any of the authors are identified as imaging specialists [25]. We also evaluated trends in authorship rates and proportion of funded studies [26]. Finally, we calculated a ratio of all published non-SRs to the number of included studies for each SR in the identified imaging journals. A value greater than '1' would indicate more non-SRs were published than the number of included studies in all SRs in a given year, while a value less than '1' would indicate the opposite.

Statistical analysis

Summary statistics are presented as the median and interquartile range (IQR), first quartile (Q_1) and third quartile (Q_3). Multiple individual linear regression models were used to assess temporal trends with year as the independent variable and the following dependent variables: publication rates of SRs, sizes of author teams, proportions of author teams with imaging specialists, proportions of SRs with meta-analyses, funding status of SRs, number of included studies per SR and number of included patients per SR. A linear regression model was also used to assess for correlation between journal impact factor (JIF) as the dependent variable and SR publication rate as the independent variable [27]. Furthermore, individual linear regression models were used to assess for correlation between citations/citations-per-year as the dependent variables and number of included studies/patients as the independent variables. Corresponding p-values and Pearson correlation coefficients (r) were calculated for each linear regression. A p-value ≤0.05 was considered to be statistically significant. The range for the correlation coefficient was defined as between -1.0 and +1.0. The sign of the correlation coefficient defined the direction of the relationship (i.e. negative or positive). The strength of the correlation was defined based on the absolute value of r as perfect ($r = 1.0$), strong ($0.8 \leq r < 1.0$), moderate ($0.5 < r \leq 0.8$), weak ($0.2 < r \leq 0.5$), very weak ($0.0 < r \leq 0.2$) or no association ($r = 0.0$). [27] Analysis was performed in SPSS version 24 (IBM, Armonk, NY, USA).

Results

Search results

The study flow diagram (Fig. 1) shows the documents search, selection and inclusion. Kappa for agreement for abstract screening was 0.91. 921 SRs published in 50 journals (no SRs found in 22 journals) were included. Appendix 4 (in the Supplementary Online Material) provides the bibliographic details for all 921 included studies.

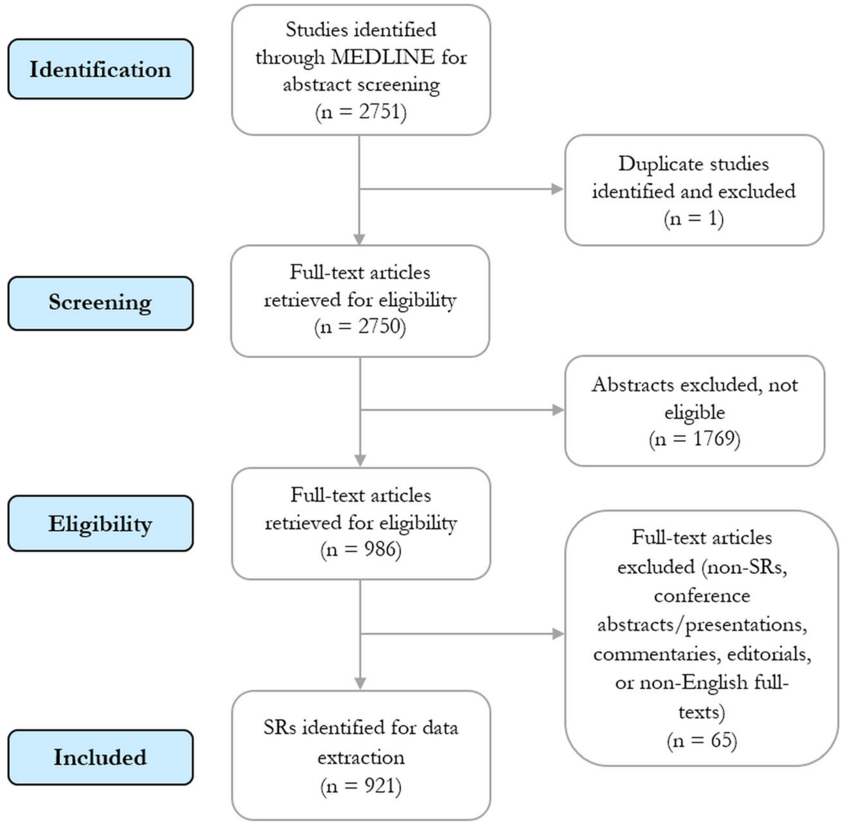

Fig. 1 Study flow diagram. The diagram shows the sequential phases of the review, as well as the included systematic reviews (SRs)

Systematic review demographics

Table 1 summarises characteristics of the included SRs. The median number of SRs published per journal between 2000 and 2016 was three (IQR 14, Q_1 0, Q_3 14). There was a moderate positive correlation between JIF and number of published SRs (r=0.54, p<0.001). Figure 2 illustrates the overall number of published SRs by year, while Fig. 3 and Supplementary Fig. 1 demonstrate the number of published SRs per year by country and continent of the corresponding author, respectively. Supplementary Fig. 2 demonstrates the number of published SRs per year according to JIF. Supplementary Fig. 3 shows the number of SRs by JIF in the top five publishing countries by corresponding author: the USA, UK, China, Netherlands and Canada.

Table 2 illustrates temporal trends for types of SR, meta-analyses and author teams, including the presence of imaging specialists and funding. Of the 428 (46.5%) studies classified as DTA SRs, 91 (21.2%) compared multiple diagnostic tests, while the remaining 337 (78.8%) reported on only one diagnostic test. Moreover, the 340 (36.9%) studies classified as 'Other' SRs covered many different topics, including evaluations of complications/harm of diagnostic tests, radiation doses of imaging tests, as well as prevalence rates of different pathologies. From the 867/921 SRs that reported the total number of included studies, the median number of included studies was 17 (IQR 20, Q_1 10, Q_3 30), while the total number of included studies for all SRs was 27,435. From the 59.8% (551/921) of studies that reported the total number of included patients, the median number of patients per SR was 945 (IQR 1,872, Q_1 415, Q_3 2,287), and the sum of all included patients was 85,276,484. There was a moderate positive correlation in the reporting of the number of included studies (r = 0.78, p<0.001) and included patients (r = 0.64, p=0.005) over time. However, for the SRs that reported these values, there was no evidence of a trend in the number of included studies (r = 0.02, p=0.47) or included patients (r = 0.02, p=0.70) over time. The median number of times cited for each SR was 11 (IQR 27, Q_1 3, Q_3 30), while the median number of citations per year was 3.1 (IQR 5.0, Q_1 1.2, Q_3 6.2). The total number of citations for all SRs was 26,961; 62/921 (6.7%) studies were cited >100 times. There was no evidence of association between citations and included studies (r = 0.01, p=0.87), citations and included patients (r = 0.003, p=0.95), citations per year and included studies (r = 0.01, p=0.87), or citations per year and included patients (r = 0.01, p=0.97). Table 3 summarises the frequency of imaging modalities and Table 4 summarises the frequency of imaging subspecialties for each included study.

The ratio of all published non-SRs (168,995) to the number of included studies (27,435) was 6.13. The proportion of SRs to all non-SRs published in imaging journals has increased more than 13-fold from 2000 (0.10%) to 2016 (1.33%), demonstrating a strong positive correlation (r = 0.94, p<0.001).

Table 1 Characteristics of the 921 included systematic reviews (SRs) published in imaging-based journals

Characteristic	Category	Number
Total number of journals (with published SRs)		72 (50)
Total number of SRs per journal (2000-2016)	0	22
	1–5	24
	6–10	4
	11–20	7
	21–50	9
	> 50	6
Total number of SRs by JIF	JIF > 4 (7 journals)	282
	2 < JIF ≤ 4 (23 journals)	414
	JIF ≤ 2 (42 journals)	222
Median number of SRs (IQR, Q_1, Q_3) per journal according to JIF	JIF > 4 (7 journals)	25 (84.0, 1.0, 85.0)
	2 < JIF ≤ 4 (23 journals)	5.0 (30.0, 0, 30.0)
	JIF ≤ 2 (42 journals)	2.5 (6.0, 0, 6.0)
Number of authors per SR (% of all SRs)	1	26 (2.8)
	2–3	169 (18.3)
	4–5	312 (33.9)
	6–10	382 (41.5)
	More than 10	32 (3.5)
SRs by country (% of all SRs)	USA	178 (19.3)
	UK	132 (14.3)
	China	131 (14.2)
	Netherlands	117 (12.7)
	Canada	54 (5.9)
	Italy	48 (5.2)
	Germany	36 (3.9)
	Australia	34 (3.7)
	Brazil	22 (2.4)
	South Korea	18 (2.0)
	France	15 (1.6)
	Switzerland	14 (1.5)
	Greece, Spain, Taiwan	13 each (1.4)
	23 Countries (<10 studies/country)	83 (8.8)
SRs by continent (% of all SRs)	Europe	436 (47.3)
	North America	234 (25.4)
	Asia	187 (20.3)
	Australia	36 (3.9)
	South America	24 (2.6)
	Africa	4 (0.4)
SRs by journal, JIF (% of all SRs)	Ultrasound in Obstetrics and Gynecology, 4.25	114 (12.4)
	European Radiology, 3.64	88 (8.6)
	Radiology, 6.80	85 (9.2)
	European Journal of Radiology, 2.59	68 (7.4)
	American Journal of Neuroradiology, 3.12	57 (6.2)
	Neuroimage, 5.46	55 (6.0)
	American Journal of Roentgenology, 2.66	36 (3.9)
	Journal of Vascular and Interventional Radiology, 2.57	36 (3.9)
	Clinical Radiology, 2.89	30 (3.3)
	41 Journals (<30 SRs/journal)	352 (38.0)

Table 1 (continued)

Characteristic	Category	Number
Number of citations per country (% of all citations; 26,961)	Netherlands	5554 (20.6)
	USA	5146 (19.1)
	UK	4459 (16.5)
	Germany	1965 (7.3)
	Canada	1545 (5.7)
	China	1496 (5.5)
	Italy	1275 (4.7)
	31 Countries (<1000 citations/country)	5532 (20.5)
Median number of citations per SR by country (IQR, Q_1, Q_3)***	Belgium	30.5 (106, 0.8, 106.8)
	Germany	30.0 (64.2, 5.3, 69.5)
	Austria	26.5 (56.0, 0.8, 56.8)
	Singapore	25.0 (21.0, 5.0, 26.0)
	Netherlands, Taiwan	20.0 (18.0 – 54.0)
	Denmark, France, Spain	17.0 (15.0 – 71.0)
	Canada, Japan, Norway, UK	16.0 (23.3 – 39.0)
	Greece	15.0 (18.0, 5.0, 23.0)
	11 countries (<15 median citations/study)	3.5 - 13.5 (9.0 – 82.0)

Note: 'Country' and 'Continent' specifically refers to 'Country of Corresponding Author' and 'Continent of Corresponding Author', respectively

JIF Journal Impact Factor, *IQR* interquartile range, Q_1 first quartile, Q_3 third quartile

*Countries with 2 or less studies excluded; **If more than 2 countries listed, Q_1 and Q_3 was not listed

Discussion

We identified 921 SRs published in imaging journals from 2000 to 2016; these included more than 27,000 primary studies and 85 million patients. The number of SRs published per year increased at a much greater rate than for non-SRs. The most common type of SR was diagnostic test accuracy, a minority of which compared multiple diagnostic tests. Most SRs incorporated meta-analyses; one in six meta-analyses incorporated IPD analysis, which can have advantages over standard meta-analysis of aggregate data in terms of reduced bias and improved reliability [28]. There was in increase in the size of the author team over time, but a decrease in the proportion of studies with an imaging specialist co-author. Given that Sardanelli et al found an association between the presence of imaging specialist co-authors and higher study quality, this trend may be of concern [25]. The proportion of non-funded SRs increased over time, while the reporting of funding increased. This improvement in reporting may be associated with improving SR quality [11].

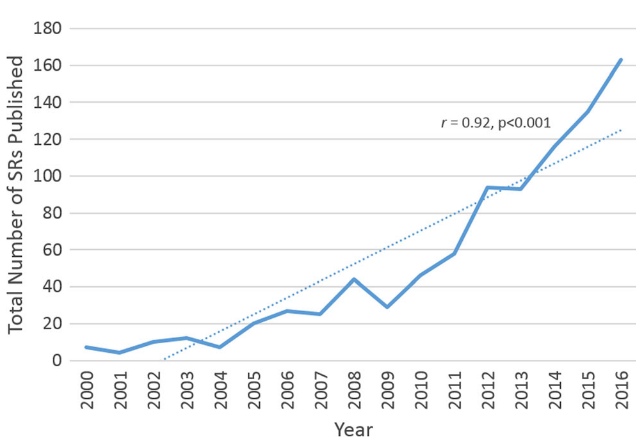

Fig. 2 Number of published systematic reviews (SRs) by year overall in 72 imaging journals with linear regression and Pearson's correlation coefficient

The most frequent modality studied was MRI, followed by computed tomography (CT) then ultrasound (US); the most frequent subspecialty was 'vascular and interventional radiology' followed by neuroradiology then gastrointestinal. Page et al identified China as the top publisher for all SRs, making up one-fifth of all SRs in the world [2, 3, 29], with a 40-fold increase between 2003 and 2011 compared to a twofold increase in the USA. However, the USA was identified as the top publishing country of SRs in imaging journals, while China was third. In the top five publishing countries, the UK had the highest proportion of SRs published in higher impact journals while China had the lowest proportion. Notably, both journal impact factor and individual citations of SRs are positively correlated with SR quality [30, 31].

No significant associations between citations and other SR characteristics were identified. However, prior studies have suggested that both quality of SRs and completeness of

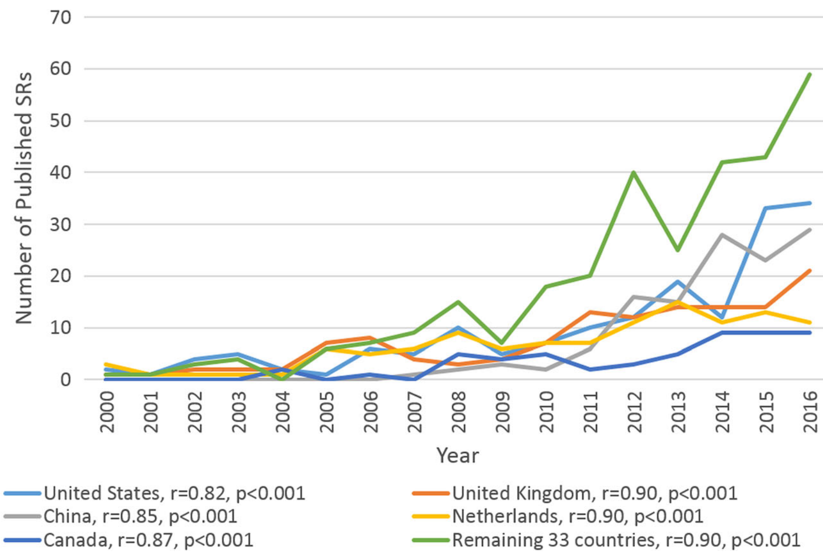

Fig. 3 Number of published systematic reviews (SRs) by year in the top five countries and the remaining 33 countries. 'Country' refers to the country of the corresponding author. Pearson's correlation coefficient (r) and *p*-value (*p*) are listed for each country in the legend

reporting are associated with subsequent citations [11, 30]. As such, support for more complete reporting may be warranted. Although none of the SRs were listed in any of the top 100 most-cited studies in the imaging literature [32–34], based on the ranges for most-cited studies lists (371–7,506 citations), it is estimated that up to six SRs (>371 citations) could potentially be included in these lists. The most cited SRs were more likely to have European corresponding authors.

Even with the rapid rise in imaging journal SR publication rates, the relative proportion of SRs compared to all publications is still fairly small at just over 1 in 100. However, Siontis et al identified that as many as 67% of SRs have at least one overlapping SR within a 3-year period [35]. Such efforts might be redirected to more impactful means, including primary research studies or SRs on another topic [36]. Furthermore, Ioannidis et al found that the number of SRs were overtaking the number of randomised controlled trials published annually [4], putting into question whether these SR publication rates can be maintained [37]. In comparison, we calculated the ratio of non-SRs to studies included in SRs as a crude estimate of whether the number of published original research studies are sufficient to sustain the number of included studies of all SRs in a given year. A value of 6.13 suggests there are sufficient primary studies; however, it may be important to track this indicator over time.

Table 2 Temporal rends of systematic reviews (SRs) published in imaging journals between 2000 and 2016

Characteristic	Category	Overall	2000	2008	2016	Pearson correlation (*r*)	*p*-value (*p*)
Type of SR	DTA	428 (46.5%)	5 (71.4%)	26 (59.1%)	62 (38.0%)	-0.58	0.015
	Therapeutic	153 (16.6%)	1 (14.3%)	8 (18.2%)	46 (28.2%)	0.19	0.471
	Other	340 (36.9%)	1 (14.3%)	10 (22.7%)	55 (33.7%)	0.40	0.107
MA and Type	Included	641 (69.6%)	7 (100.0%)	28 (63.6%)	120 (73.6%)	0.10	0.691
	IPD MA	102 (11.1%)	1 (14.3%)	6 (13.6%)	20 (12.3%)	0.19	0.475
	Network MA	1 (0.1%)	0	0	1 (0.6%)	N/A	N/A
Author Team	Median size	5 (IQR 3, Q_1 4, Q_3 7)	4 (IQR 2, Q_1 3.5, Q_3 5.5)	4 (IQR 3, Q_1 3, Q_3 6)	6 (IQR 4, Q_1 4, Q_3 8)	0.20	<0.001
	Imaging Specialist	620 (67.3%)	7 (100.0%)	35 (79.5%)	106 (65.0%)	-0.57	0.017
Funding (%)	Yes	281 (30.5%)	3 (42.9%)	13 (29.5%)	56 (34.4%)	0.19	0.464
	No	141 (15.3%)	0	6 (13.6%)	33 (29.9%)	0.57	<0.001
	NR	499 (54.2%)	4 (57.1%)	25 (56.8%)	74 (44.8%)	-0.50	l0.040

Note: Percentages given for the 2000, 2008 and 2016 columns are based on the total values for each respective year, while the percentage given for the overall column is based on all included SRs (921). The Pearson correlation coefficient and *p*-value for each category was based on the annual proportions (%) for every year from 2000 to 2016

MA meta-analysis, *DTA* Diagnostic Test Accuracy, *IPD* Individual Patient Data, *NR* not reported, *IQR* interquartile range, Q_1 first quartile, Q_3 third quartile, *N/A* not applicable

Table 3 Frequency of imaging modalities of included studies

Imaging	Number of studies	Proportion (%)
Plain films	48	5.2
CT	233	25.3
MRI	297	32.2
US	230	25.0
Fluoroscopy	13	1.4
IR	118	12.8
Nuclear Medicine	124	13.5
Other	117	12.7

Note: Proportion adds up to >100% as each study may have included multiple imaging modalities

CT computed tomography, *MRI* magnetic resonance imaging, *US* ultrasound, *IR* interventional radiology

It is interesting to note that a majority of systematic reviews were either DTA and/or used IPD. This is an important distinction since these systematic reviews have specific methodological and reporting requirements. DTA systematic reviews should draw their methodological guidance from the Cochrane Handbook of DTA Reviews, and reporting should be guided by PRISMA-DTA, rather than PRISMA [13–15]. Similarly, studies performing IPD meta-analysis should be guided by principles outlined by PRISMA-IPD [21]. Imaging systematic review methods may evolve to include additional methods, such as network meta-analysis [22]. Authors, editors, and reviewers should keep abreast of the latest methodological and reporting guidance; the PRISMA group, EQUATOR Network and Cochrane are all excellent resources for such updates [38–40].

Table 4 Frequency of imaging subspecialty of included studies

Subspecialty imaging	Number of studies	Proportion (%)
Breast	42	4.6
Cardiac	67	7.3
Gastrointestinal	126	13.7
Genitourinary	75	8.1
Head and neck	71	7.7
Musculoskeletal	88	9.6
Neuroradiology	139	15.1
Nuclear medicine	124	13.5
Obstetric	103	11.2
Other	117	12.7
Paediatric	16	1.7
Thoracic	51	5.5
Vascular and IR	155	16.8

Note: Proportion adds up to >100% as each study may have included multiple imaging modalities

IR interventional radiology

Limitations to this review include that the SRs were from imaging journals only. As such, trends for imaging SRs published in other journals are not represented, which may introduce a selection bias. Furthermore, for citation analysis, only citations per year were evaluated without accounting for the month of publication; this may skew the citations-per-year value more in SRs that were published more recently. In addition, we underestimate the number of included studies for all SRs included, as these values were not reported for all SRs. Another limitation was a lack of evaluation of SR quality and completeness of reporting; although this has been investigated previously [11], evaluation of these factors may be warranted in future studies given the rapid increase in SR publication. Finally, there is potential for publication bias, as a search for unpublished SRs in the grey literature was not conducted.

In conclusion, the number of SRs being published in imaging journals is increasing at a rate much greater than that of non-SRs, but still make up just over 1% of all studies. SRs are more commonly published in high impact journals; the USA is the most frequent country of publication while Europe is the most frequent continent. The size of SR author teams is increasing while the proportion with imaging specialists is decreasing. The most common type of SR was DTA, most SRs performed meta-analyses, and a minority of these performed IPD meta-analysis. Authors, reviewers and editors should keep abreast of the latest reporting and methodological guidance as systematic review methods continue to evolve.

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Compliance with ethical standards

Guarantor The scientific guarantor of this publication is Matthew McInnes

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Statistics and biometry One of the authors has significant statistical expertise (Dr McInnes).

Informed consent Written informed consent was not required for this study because this study was an evaluation of published literature.

Ethical approval Institutional Review Board approval was not required because this study was an evaluation of published literature.

Methodology
- retrospective
- cross sectional study
- multicenter study

References

1. Murad MH, Montori VM (2013) Synthesizing evidence: shifting the focus from individual studies to the body of evidence. JAMA 309(21):2217–2218
2. Page MJ, Shamseer L, Altman DG et al (2016) Epidemiology and Reporting Characteristics of Systematic Reviews of Biomedical Research: A Cross-Sectional Study. PLoS Med 13(5):e1002028
3. Moher D, Tetzlaff J, Tricco AC, Sampson M, Altman DG (2007) Epidemiology and reporting characteristics of systematic reviews. PLoS Med 4(3):e78
4. Ioannidis JP (2016) The Mass Production of Redundant, Misleading, and Conflicted Systematic Reviews and Meta-analyses. Milbank Q 94(3):485–514.5
5. Berkman ND, Lohr KN, Ansari MT et al (2015) Grading the strength of a body of evidence when assessing health care interventions: an EPC update. J Clin Epidemiol 68(11):1312–1324
6. Guyatt GH, Sackett DL, Sinclair JC, Hayward R, Cook DJ, Cook RJ (1995) Users' guides to the medical literature. IX. A method for grading health care recommendations. Evidence-Based Medicine Working Group. JAMA 274(22):1800–1804
7. Lundberg GD (2016) Who Do You Trust? MedScape, New York. Available via https://www.medscape.com/viewarticle/871378. Accessed 15 Dec 2016
8. Bastian H, Glasziou P, Chalmers I (2010) Seventy-five trials and eleven systematic reviews a day: how will we ever keep up? PLoS Med 7(9):e1000326
9. Ioannidis JP, Greenland S, Hlatky MA et al (2014) Increasing value and reducing waste in research design, conduct, and analysis. Lancet 383(9912):166–175
10. Moher D, Glasziou P, Chalmers I et al (2016) Increasing value and reducing waste in biomedical research: who's listening? Lancet 387(10027):1573–1586
11. Tunis AS, McInnes MD, Hanna R, Esmail K (2013) Association of study quality with completeness of reporting: have completeness of reporting and quality of systematic reviews and meta-analyses in major radiology journals changed since publication of the PRISMA statement? Radiology 269(2):413–426
12. McGrath TA, McInnes MD, Korevaar DA, Bossuyt PM (2016) Meta-Analyses of Diagnostic Accuracy in Imaging Journals: Analysis of Pooling Techniques and Their Effect on Summary Estimates of Diagnostic Accuracy. Radiology 281(1):78–85
13. Moher D, Liberati A, Tetzlaff J, Altman DG, Group P (2009) Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med 6(7):e1000097
14. Higgins J, Green S (2011) Cochrane handbook for systematic reviews of interventions. The Cochrane Collaboration, London. Available via http://training.cochrane.org/handbook. Accessed 10 Dec 2016
15. McInnes MDF, Moher D, Thombs BD et al (2018) Preferred Reporting Items for a Systematic Review and Meta-analysis of Diagnostic Test Accuracy Studies: The PRISMA-DTA Statement. JAMA 319(4):388–396
16. Issa Y, Kempeneers MA, van Santvoort HC, Bollen TL, Bipat S, Boermeester MA (2017) Diagnostic performance of imaging modalities in chronic pancreatitis: a systematic review and meta-analysis. Eur Radiol 27(9):3820–3844
17. Sevcenco S, Spick C, Helbich TH et al (2017) Malignancy rates and diagnostic performance of the Bosniak classification for the diagnosis of cystic renal lesions in computed tomography - a systematic review and meta-analysis. Eur Radiol 27(6):2239–2247
18. Porté F, Uppara M, Malietzis G et al (2017) CT colonography for surveillance of patients with colorectal cancer: Systematic review and meta-analysis of diagnostic efficacy. Eur Radiol 27(1):51–60
19. Connolly MJ, McInnes MDF, El-Khodary M, McGrath TA, Schieda N (2017) Diagnostic accuracy of virtual non-contrast enhanced dual-energy CT for diagnosis of adrenal adenoma: A systematic review and meta-analysis. Eur Radiol 27(10):4324–4335
20. Lee SY, Kim HJ, Shin YR, Park HJ, Lee YG, Oh SJ (2017) Prognostic significance of focal lesions and diffuse infiltration on MRI for multiple myeloma: a meta-analysis. Eur Radiol 27(6): 2333–2347
21. Stewart LA, Clarke M, Rovers M et al (2015) Preferred Reporting Items for Systematic Review and Meta-Analyses of individual participant data: the PRISMA-IPD Statement. JAMA 313(16):1657–1665
22. Hutton B, Salanti G, Caldwell DM et al (2015) The PRISMA extension statement for reporting of systematic reviews incorporating network meta-analyses of health care interventions: checklist and explanations. Ann Intern Med 162(11):777–784
23. Shojania KG, Bero LA (2001) Taking advantage of the explosion of systematic reviews: an efficient MEDLINE search strategy. Eff Clin Pract 4(4):157–162
24. Web of Science (2017). Clarivate Analytics, Boston. Available via https://login.webofknowledge.com. Accessed 5 Jan 2017
25. Sardanelli F, Bashir H, Berzaczy D et al (2014) The role of imaging specialists as authors of systematic reviews on diagnostic and interventional imaging and its impact on scientific quality: report from the EuroAIM Evidence-based Radiology Working Group. Radiology 272(2):533–540
26. Dang W, McInnes MD, Kielar AZ, Hong J (2015) A Comprehensive Analysis of Authorship in Radiology Journals. PLoS One 10(9):e0139005
27. Zou KH, Tuncali K, Silverman SG (2003) Correlation and simple linear regression. Radiology 227(3):617–622
28. Riley RD, Lambert PC, Abo-Zaid G (2010) Meta-analysis of individual participant data: rationale, conduct, and reporting. BMJ 340:c221
29. Ioannidis JP, Chang CQ, Lam TK, Schully SD, Khoury MJ (2013) The geometric increase in meta-analyses from China in the genomic era. PLoS One 8(6):e65602
30. van der Pol CB, McInnes MD, Petrcich W, Tunis AS, Hanna R (2015) Is quality and completeness of reporting of systematic reviews and meta-analyses published in high impact radiology journals associated with citation rates? PLoS One 10(3):e0119892
31. Fleming PS, Koletsi D, Seehra J, Pandis N (2014) Systematic reviews published in higher impact clinical journals were of higher quality. J Clin Epidemiol 67(7):754–759
32. Brinjikji W, Klunder A, Kallmes DF (2013) The 100 most-cited articles in the imaging literature. Radiology 269(1):272–276
33. Pagni M, Khan NR, Cohen HL, Choudhri AF (2014) Highly cited works in radiology: the top 100 cited articles in radiologic journals. Acad Radiol 21(8):1056–1066
34. Yoon DY, Yun EJ, Ku YJ et al (2013) Citation classics in radiology journals: the 100 top-cited articles, 1945-2012. AJR Am J Roentgenol 201(3):471–481
35. McInnes MD, Bossuyt PM (2015) Pitfalls of Systematic Reviews and Meta-Analyses in Imaging Research. Radiology 277(1):13–21
36. Glasziou P, Altman DG, Bossuyt P et al (2014) Reducing waste from incomplete or unusable reports of biomedical research. Lancet 383(9913):267–276
37. Siontis KC, Hernandez-Boussard T, Ioannidis JP (2013) Overlapping meta-analyses on the same topic: survey of published studies. BMJ 347:f4501
38. PRISMA: Transparent Reporting of Systematic Reviews and Meta-analyses (2015) Preferred Reporting Items for a Systematic Review and Meta-analysis, Ottawa. Available via http://www.prisma-statement.org. Accessed 13 Feb 2018

39. EQUATOR Network: Enhancing the Quality and Transparency of Health Research (2018) EQUATOR Network, Oxford. Available via http://www.equator-network.org. Accessed 13 Feb 2018

40. Cochrane: Trusted evidence. Informed decisions. Better health. (2018) Cochrane, London. Available via http://www.cochrane.org. Accessed 13 Feb 2018.